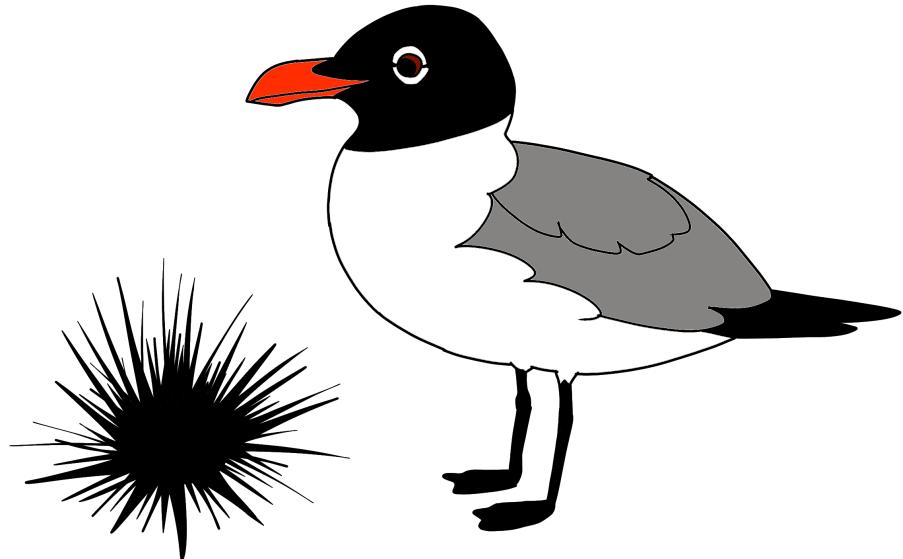


# **Water Quality Div C**

# **BirdSO Invitational**



- The rules for this event have been adapted for our virtual tournament and follow the 2020-2021 National Rules.
- The maximum number of obtainable points on this exam is 300 [Part 1: 106 | Part 2: 194].
- If you have any questions or concerns regarding this exam, feel free to contact me through the following email once the testing window has concluded: shrayenpatel@utexas.edu (Part 1) and krishjayarapu@gmail.com (Part 2).
- Exam Authors: Shrayen Patel, The University of Texas at Austin, B.S. Biology '24 and Krish Jayarapu, Carmel HS, '22

**Names:** \_\_\_\_\_ **KEY** \_\_\_\_\_ **Team:** \_\_\_\_\_

**Part 1 Score: 106/106 | Part 2 Score: 194/194 | TOTAL SCORE: 300/300**

## **Part 1 (Written by Shrayen)**

1. [1] A black-box hydrological model can be standardized to globally model a forecast with respect to the water cycle.
- True
  - False

**B**

2. [1] An antecedent precipitation index (API) model is a contributing element to a black-box hydrological model.
- True
  - False

**A**

3. [1] Which of the following is the largest source of phosphorus on Earth?
- Soil
  - Rock
  - Plants
  - Animals
  - Laboratories

**B**

4. [1] Nitrification changes ammonia into nitrates that are primarily not usable by plants.
- True
  - False

**B**

5. [1] "Dead zones" can develop over time in a body of water if excessive phosphorus and nitrogen continue seeping into the environment.
- True
  - False

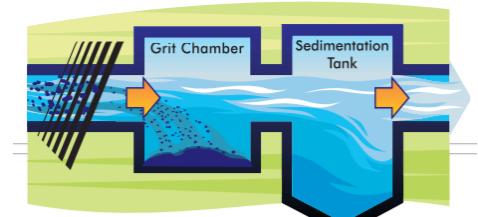
**A**

6. [1] The Clean Water Act requires that municipal wastewater treatment plant discharges meet a minimum of \_\_\_\_\_ treatment.

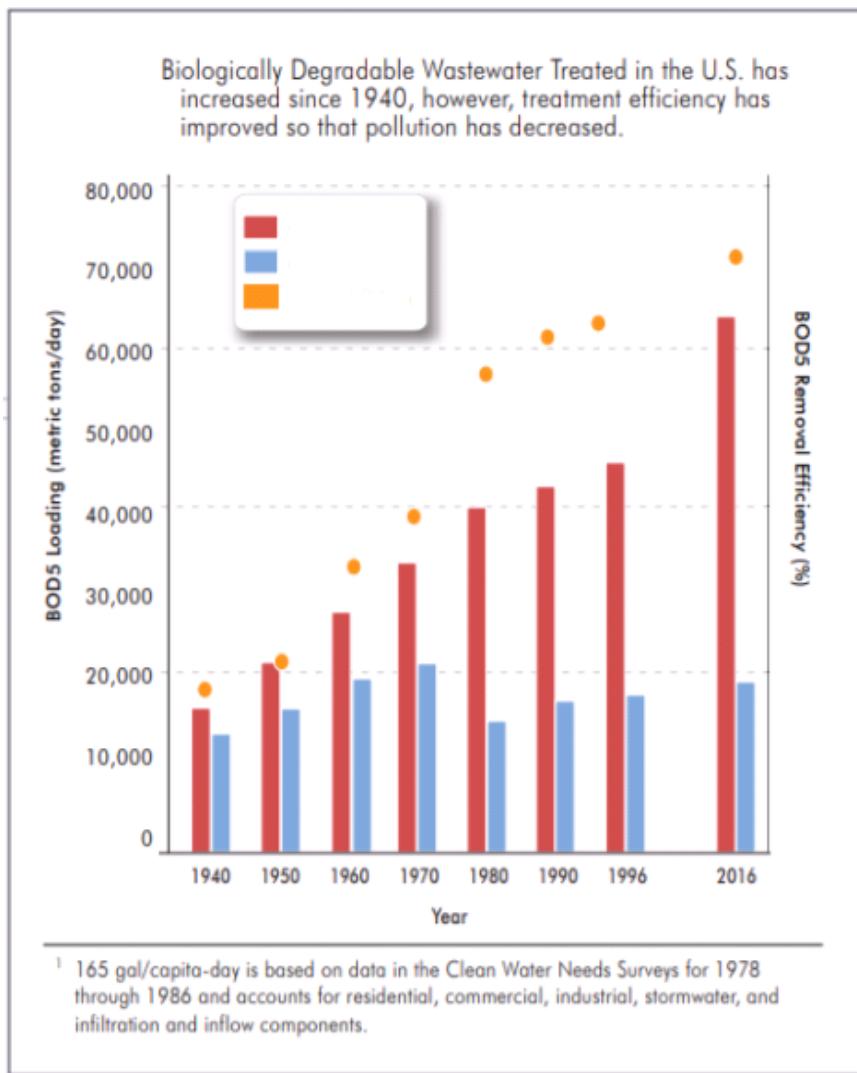
### **Secondary**

7. [1] Which stage of wastewater treatment is depicted by the diagram?
- Primary
  - Secondary
  - Tertiary

**A**



8. [5] Using the diagram below, which color (red or blue) represents the influent and which color (red or blue) represents the effluent? In ONE sentence, explain how you came to this conclusion. What's the significance of the trend in orange dots?



**red - influent [+1], blue - effluent [+1], effluent should have lower BOD than influent otherwise there's no reason for the treatment process to occur [+1], orange dots signify BOD removal efficiency has increased OVER TIME [+1] // [+1] bonus if earned all other points for this question!**

9. [1] A septic tank is a tank buried in the ground used to treat sewage without the presence of which element?

- Fluorine
- Carbon
- Oxygen
- Nitrogen
- Phosphorous
- Sulfur

C

10. [1] When added to wastewater, lime can help reduce the concentration of phosphorus by approximately \_\_\_ %.

- a. 15
- b. 30
- c. 45
- d. 60
- e. 75
- f. 90

**F**

11. [4] Which of the following water contaminants are correctly paired with a stable treatment option? Select ALL that apply.

- a. Arsenic - Adsorption
- b. Iron - Oxidation
- c. Manganese - Adsorption
- d. Arsenic - Reverse Osmosis
- e. Manganese - Oxidation
- f. Iron - Reverse Osmosis

**ABCE**

12. [1] Watershed management accomplishes which of the following?

- a. Revives greenery
- b. Reduces floods
- c. Improves soil moisture
- d. A & B only
- e. B & C only
- f. A, B, & C

**F**

13. [3] Which of the following are true regarding gully plugs, which assist in watershed management? Select ALL that apply.

- a. Slows water speed
- b. Are synonymously referred to as “check dams”
- c. Provide easier passage for fish
- d. Can increase groundwater salinity
- e. Can clog up with silt
- f. Are typically not cost effective

**ABE**

14. [1] Natural erosion produces approximately \_\_\_ % of the total sediment in the United States, whereas accelerated erosion accounts for the other \_\_\_ %.

- a. 40, 60
- b. 20, 80
- c. 30, 70
- d. 70, 30
- e. 80, 20
- f. 60, 40

**C**

15. [1] Over \_\_\_ % of the world's coral reefs have died in the past 30 years.

**50 [THROWN OUT EVERYONE AWARDED 1 POINT]**

16. [4] Degree heating weeks (DHWs) are used to represent the accumulation of thermal stress for corals. Which of the following statements are true? Select ALL that apply.

- a. Three DHWs are equivalent to three weeks at one degree above the expected summertime maximum temperature.
- b. Three DHWs are equivalent to one week at three degrees above the expected summertime maximum temperature.
- c. Coral bleaching becomes likely at 2 DHWs.
- d. Coral bleaching becomes likely at 4 DHWs.
- e. Complete coral mortality becomes likely at 8 DHWs.
- f. Complete coral mortality becomes likely at 10 DHWs.

**ABDE**

17. [1] Harmful algal blooms are more likely to occur in slow-moving water than rapid-moving water, disregarding the other factors necessary for one to occur.

- a. True
- b. False

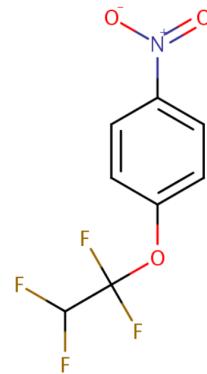
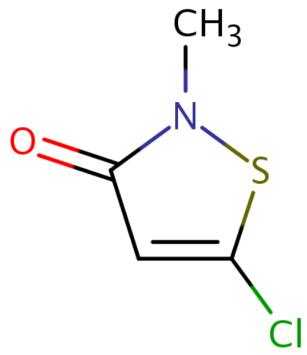
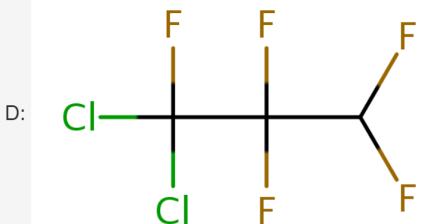
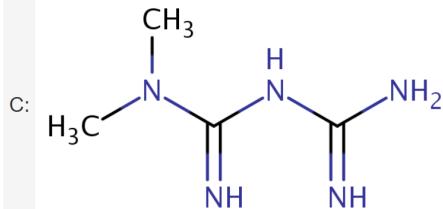
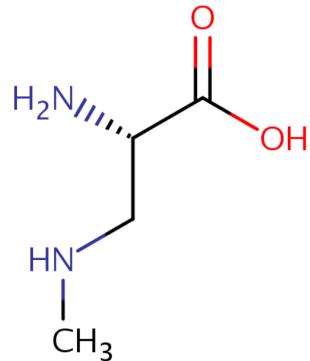
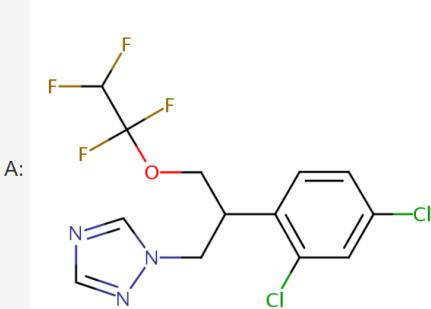
**A**

18. [1] Which bond prevents per- and polyfluorinated alkyl (PFAS) chemicals from degrading in the environment?

- a. Carbon-hydrogen
- b. Carbon-fluorine
- c. Carbon-carbon
- d. Carbon-chlorine

**B**

19. [3] Based on their chemical structure as pictured below, which of the following are categorized as PFAS chemicals? Select ALL that apply.



**ADF**

20. [1] The five ocean garbage patches are constantly moving and changing with the currents.

- a. True
- b. False

**A**

21. [1] Out of the five major ocean garbage patches, how many are near (or a part of) US waters?

**2**

Use the following image (Organism A) for the next FIVE questions (22-26):

22. [1] What is the common name of organism A?

- a. Triton
- b. Barramundi Cod
- c. Flamingo Tongue Snail
- d. Banded Coral Shrimp

C



23. [4] Which of the following are true regarding organism A? Select ALL that apply.

- a. Organism A consumes gorgonia
- b. Organism A consumes soft coral
- c. Organism A typically digests toxins consumed from its prey
- d. Organism A typically stores toxins consumed from its prey
- e. Organism A displays aposematic coloration
- f. Organism A typically reaches a size of 2-3 inches during adulthood

ABDE

24. [1] After it dies, what color is the shell of organism A?

- a. Black
- b. Orange-Yellow
- c. Brown
- d. White

D

25. [2] What causes organism A to experience bilateral symmetry throughout its life?

**a twisting motion [+1] that happens during the larval stage of life [+1]**

26. [8] Explain the method of sexual reproduction members of organism A use. Additionally, explain the reasoning behind the location where eggs are laid by females of organism A.

**Male approaches female and crawls up onto right side of her shell [+1], male extends white tube under edge of female's shell and begins mating [+1], after up to 4 hours of mating and four days, female will lay encapsulated white translucent eggs onto bare axis of gorgonians, which is exposed from snail's feedings [+1], areas are chosen for eggs since absence of gorgonian's tissue toxins [+1], each egg capsule contains up to 300 embryos, resulting in speckled appearance [+1], after ten days, capsules hatch and young free-swimming larvae disperse [+1] // bonus [+2] if earned all previous points for this question**

Use the following image (Organism B) for the next FOUR questions (27-30):

27. [1] What is the common name of organism B?

**Snapper**

28. [1] Members of organism B found in deeper waters tend to be "redder" than those found in shallower waters.

- a. True
- b. False



**A**

29. [1] Females of organism B reach sexual maturity by \_\_\_\_ years old.

**2**

30. [1] Organism B is listed as endangered on the IUCN Red List of Threatened Species.

- a. True
- b. False

**B**

Use the following image (Organism C) for the next SIX questions (31-36):

31. [1] What is the common name of organism C?

**Parrotfish**

32. [1] Organism C spends about 40% of its day eating algae off of coral reefs.

- a. True
- b. False



**B**

33. [3] Members of Organism C have a second set of teeth located in the back of their throat. What are these teeth specifically called and what other organism from the list for this event also has the same second set of teeth?

**pharyngeal teeth [+1], moray eel [+1] // [+1] bonus if both correct**

34. [1] Organism C is nocturnal.

- a. True
- b. False

**B**

35. [1] Organism C swims exclusively using its \_\_\_\_\_ fins.

**Pectoral**

36. [1] What does organism C excrete ground-up coral as?

- a. Dirt
- b. Leaves
- c. Sand

**C**

Use the following image (Organism D) for the next THREE questions (37-39):

37. [1] Organism D is fleshy algae.

- a. True
- b. False

**B**

38. [1] Organism D is a(n) \_\_\_\_\_.

- a. Plant
- b. Animal



**B**

39. [1] Members of organism D have tentacles that can be used to sting prey; these tentacles are specifically called \_\_\_\_\_ . (Use plural form)

**nematocysts**

Use the following image (Organism Z) for the next THREE questions (40-42):

40. [1] What is the common name of organism Z?

- a. Fleshy Algae
- b. Hard Coral
- c. Giant Clam
- d. Sea Cucumber
- e. Sponge



**E**

41. [1] Organism Z prefers living in areas with strong currents.

- a. True
- b. False

**B**

42. [1] After finding a location to live, organism Z remains completely sessile for the remainder of its life.

- a. True
- b. False

**A**

43. [10] For EACH organism from the 2020-2021 Water Quality species list pictured below, identify the organism and its common name (example format: "M - Lobster"). If an organism is NOT part of the 2020-2021 Water Quality species list, do NOT name it below, as negative points ARE possible for this question.

*You may be asking yourself "why would he do this to us?!" and the answer is: to ensure you're actually able to distinguish between organisms and aren't just guessing from the given list!!*



**E - butterflyfish, F - butterflyfish, H - sweetlips, I - sweetlips, J - bumphead parrotfish, K - humpheadwrasse, O - nassau grouper, P - grouper // [+1] for each correct answer, [-1] for each incorrect answer, 0 pts if blank, [+2] bonus if got all correct!**

44. [1] Temperature & nitrates have a direct correlation with each other.

- a. True
- b. False

**A**

45. [1] Temperature & phosphates have a direct correlation with each other.

- a. True
- b. False

**A**

46. [1] Temperature & biological oxygen demand (BOD) have an indirect correlation with each other.

- a. True
- b. False

**B**

47. [1] If the Secchi depth measured is 1 meter, the range of approximate depth that light can penetrate into the body of water is also 1 meter.

- a. True
- b. False

**B**

48. [1] The transmission light method of detecting turbidity is used for samples of water with an apparent high turbidity.

- a. True
- b. False

**A**

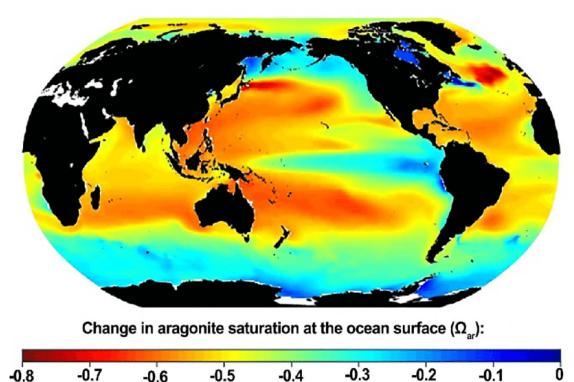
49. [2] If a sample of water is NOT diluted, how can its biological oxygen demand (BOD) be calculated from it's dissolved oxygen (DO) levels?

**By subtracting its initial DO level from its final DO level [+2]**

50. [1] Using the diagram below, will seawater be less acidic in the blue regions of the map or the red regions in the map?

- a. Blue
- b. Red

**A**

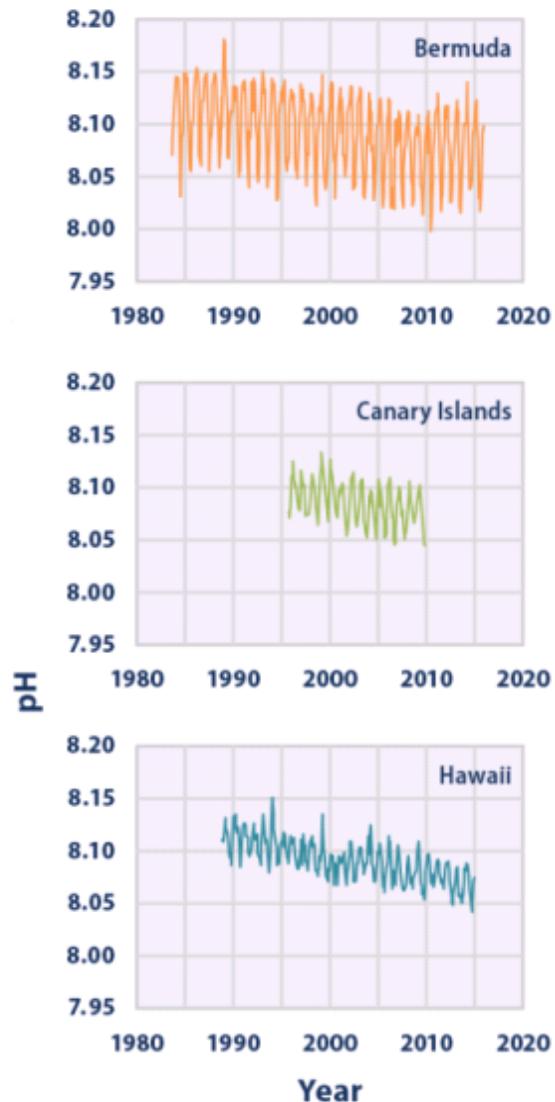
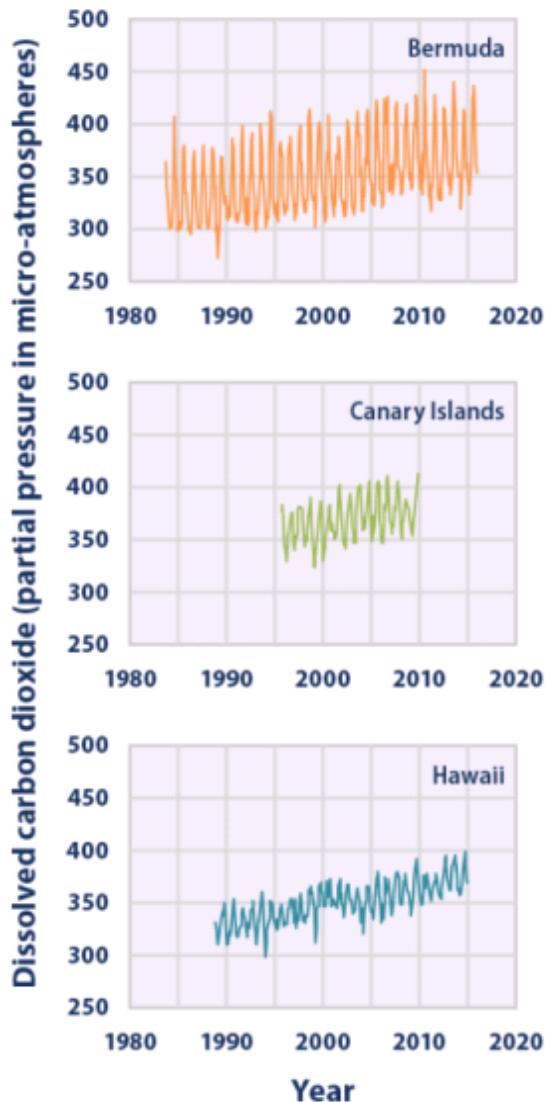


51. [1] When  $\Omega < 1$ , seawater is said to be \_\_\_\_\_ with respect to aragonite.

- a. Undersaturated
- b. Saturated
- c. Supersaturated

A

52. [2] Using the diagram below, can you conclude the relationship between dissolved carbon dioxide and acidity is direct or inverse? Briefly explain why.



direct [+1], pH and acidity are inverse - the diagram shows an inverse relationship between dissolved CO<sub>2</sub> and pH [+1]

53. [1] Suspended solids are classified as particles that will not pass through a \_\_\_ micron filter.

54. [3] Given the initial dissolved oxygen (DO) level is 10 mg/L, if 10 mL of wastewater is added to a 300 mL incubation flask and the final DO level after 5 days is 20 mg/L, calculate the biological oxygen demand (BOD) of the sample in mg/L. Assume no seed has been added to the sample.

**300**

55. [1] In the ratio method of detecting turbidity, a single detector is used.

- a. True
- b. False

**B**

56. [1] For the scattering light method of detecting turbidity, the angle between the photodetector and incident light is 180°.

- a. True
- b. False

**B**

57. [1] A visual turbidimeter has poor accuracy.

- a. True
- b. False

**A**

58. [4] Which of the following are true regarding tests for phosphorus? Select ALL that apply.

- a. As a part of the Acid Hydrolyzable Phosphate test, condensed phosphates are hydrolyzed into orthophosphate.
- b. Orthophosphate is one phosphorus atom bonded to two oxygen atoms.
- c. To measure all of the particulate orthophosphate, it's necessary to use a total phosphorus test.
- d. In a sample, total phosphorus concentrations will always be smaller than orthophosphate concentrations.
- e. The 3 main ways to test for phosphorus in water are via the orthophosphate test, the acid hydrolyzable phosphate test, and the total phosphorus test.
- f. Total phosphorus is typically displayed as a "P."

**ACEF**

59. [3] Which of the following are true regarding pH? Select ALL that apply.

- a. Acid rain that accumulates in a body of water can affect the water's pH
- b. A pH of 5.0 is ten times more acidic than a pH of 6.0
- c. A pH of 5.0 is ten times less acidic than a pH of 6.0
- d. Most marine organisms can survive in environments with wide ranges of pH values.
- e. Temperature and pH have an inverse relationship with each other.
- f. Temperature and pH have a direct relationship with each other.

**ABE**

60. [2] On average, which states have "harder" water than Pennsylvania? Select ALL that apply.

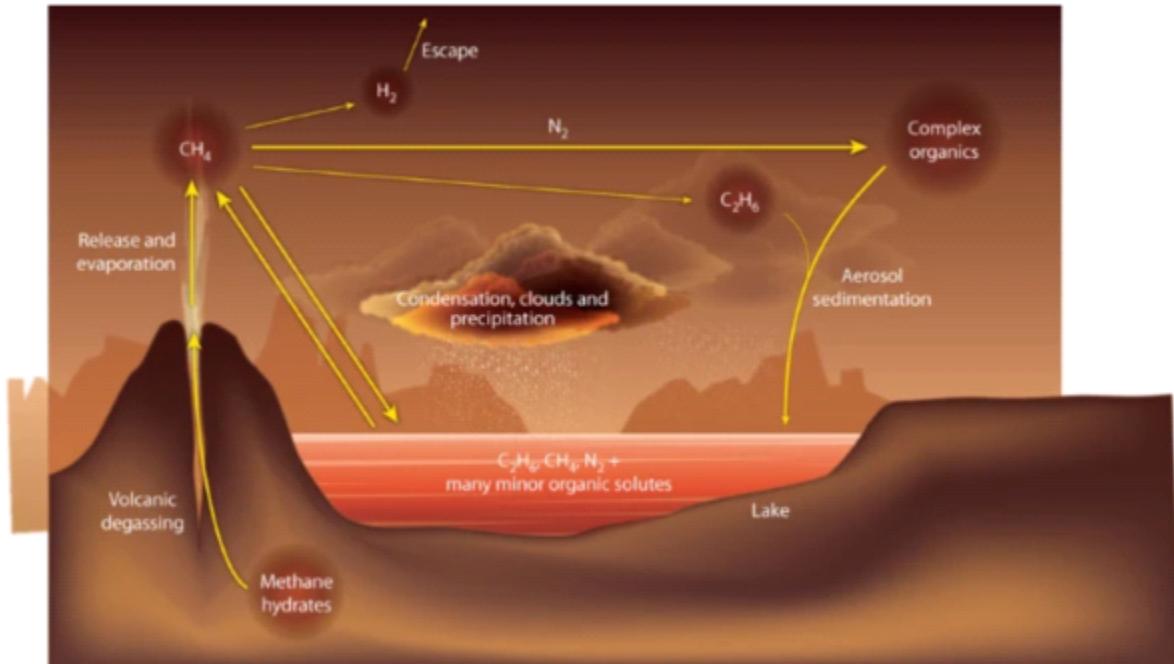
- a. Mississippi
- b. North Carolina
- c. Wyoming
- d. Oregon
- e. New Hampshire
- f. Colorado

**CF**

## Part 2 (Written by Krish)

### Astrobiology?

Titan is the largest moon at Saturn. Unlike Earth, it has a lot of methane/ethane lakes instead of water. The bottom left of the diagram shows methane hydrates. The lakes on Titan also have a lot of nitrogen dissolved within them.



61. [1] What anesthetic effect would you have on this moon, especially when diving?

**Nitrogen Narcosis but accepted symptoms under low oxygen conditions**

62. [1] There are many parallels of methane hydrates on Titan to those on Earth. On Earth, the frequency and concentration of methane hydrates closer to the surface increases with \_\_\_\_\_ (lowering/increasing) temperatures.

- a. Increasing
- b. Decreasing

**A**

63. [1] Methane-based life forms can be possible to exist. Azotosomes, a microscopic sphere, are the proposed alternative to cell membranes here on Earth. They are made up of acrylonitrile (vinyl cyanide) which is found on Titan. Unfortunately, more studies showed that this would not work. With the extreme cold and little sunlight that Titan gets, why might azotosomes be unable to form?

**Thermodynamically unfavorable**

64. [1] Based on what you know about the polarity of acrylonitrile and methane, describe the structure of an azotosome.

**Hydrophobic groups on the outside, etc.**

### Biomagnification

Mercury is an incredibly toxic element to many organisms mainly entering systems through anthropogenic sources. Gold mining and coal combustion are the leading sources of this.

65. [1] Under anoxic conditions, bacteria transform mercury to methylmercury (MeHg).

- a. True
- b. False

**A**

66. [1] Which of the following is true of MeHg in marine organisms? Select ALL that apply.

- a. Binds to sulfhydryl groups of amino acids
- b. Readily absorbed from the gastrointestinal tract
- c. Crosses blood-brain barrier

**ABC**

67. [1] There is a correlation between selenium (Se) levels and MeHg in many organisms. Which of the following are possible explanations of this?

- a. Se related to metal binding proteins
- b. Binding of Hg as insoluble Se compounds
- c. All of the above
- d. None of the above

**C**

68. [4] Isotope analysis can be used to determine trophic positions in ecosystems. One model shown below does this and calculates the trophic position relative to a copepod (*C. finmarchicus*), a primary consumer with a trophic level of 2. “N\_consumer” is the species of study. Write the lowercase delta as “d”. Use underscore to express subscripts. Use “^” to express superscripts. Or you can type it normally like a cool kid :D.

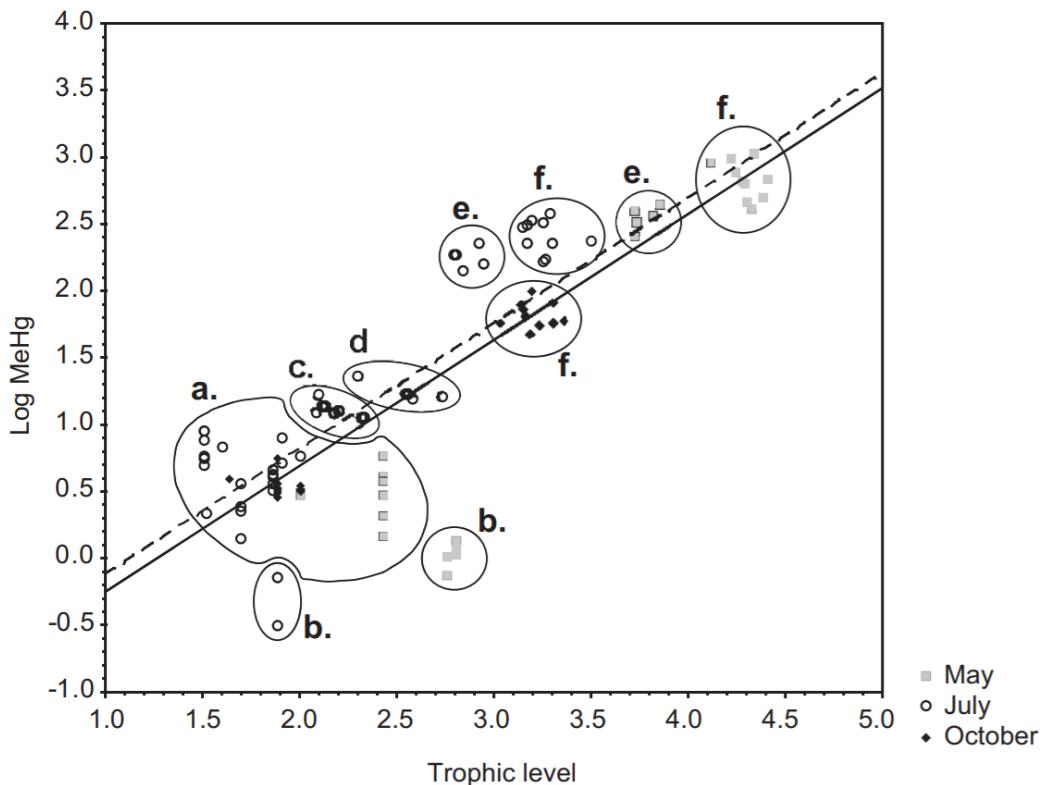
$$TP_{\text{consumer}} = 2 + (\delta^{15}\text{N}_{\text{consumer}} - \delta^{15}\text{N}_{C.\text{finmarchicus}})/3.8$$

Birds just have to be special. Piscivorous birds just seem to have a lesser isotopic fractionation than what was assumed for the above equation. For a bird, if the fractionation factor of 2.4‰ is appropriate, derive a new equation for a piscivorous bird.

$$TP_{\text{bird}} = 3 + [\delta^{15}\text{N}_{\text{bird}} - (\delta^{15}\text{N}_{C.\text{finmarchicus}} + 2.4)]/3.8$$

**3 comes from new trophic position; if we assume preveq to be og then we add 2.4 to find new eq relative to prev**

69. [3] It is expected to find the highest Hg and MeHg concentration in birds and the lowest in zooplankton. The following is a graph showing trophic level (estimated from isotopes) versus log (base 10) transformed concentrations of MeHg (Adapted from Ruus et al. 2015).



Match the following organisms with their respective letter on the diagram.

Organisms: Krill, Kittiwake (bird), Capelin (fish), Little Auk (bird), Zooplankton, Polar Cod (fish)

**a: zooplankton, b: krill, c: capelin, d: polar cod, e: little auk, f: kittiwake | [+0.5] each**

70. [1] There are two regression lines on this diagram. Removal of which species will result in a shift from the bold to the dashed line? (Looking for the letter.)

**b: krill**

71. [4] There are lower concentrations of Hg in birds as the months pass. Which of the following are plausible reasons for this? Select ALL that apply.

- a. Increased elimination of Hg, bound to feather keratin, through molting.
- b. Female birds may also excrete Hg via their eggs.
- c. Diet transition from fish to invertebrates.
- d. Decrease in the  $\delta^{15}\text{N}$  baseline.

**ABC**

72. [1] Hg accumulation depends on latitude, where there is higher biomagnification at higher latitude.

- a. True
- b. False

**A**

### Eurypterida (jk this isn't fossils)

Eurypterids are sea scorpions within the phylum Arthropoda. They were large fearsome predators.

73. [1] Based on what you know about Arthropods and “scorpions”, do you predict them to be benthic?

- a. Yes
- b. No

**A**

74. [2] The ‘mass-moult-mate’ hypothesis explains some of the behavior of Eurypterids. The following quote describes this behavior.

“The mass-moult-mate hypothesis has been proposed to explain such occurrences, whereby eurypterids undertook mass migrations into near shore settings and lagoons to moult, mate and spawn, similar to the behaviour of living horseshoe crabs.” (Vrazo & Braddy, 2011)

Some fish exhibit a similar behavior such as barracuda but instead adults will breed in mangrove swamps even though they normally are found in the open ocean. Explain why it is beneficial for breeding to occur at mangrove swamps.

**Find shelter among the mangrove roots as juveniles, head out to forage in the seagrass beds as they grow, and move into the open ocean as adults. Essentially, increasing survival.**

### Stressed Ecosystems

At severe levels of eutrophication, HABs can occur leading to hypoxia.

75. [1] HAB species include which of the following? Select ALL that apply.

- a. Dinoflagellates
- b. Diatoms
- c. Raphidophytes
- d. Cyanobacterium

**ABCD**

76. [1] Which of the following is not a toxin resulting from HABs?

- a. Anatoxin
- b. Microcystins
- c. Nodularin
- d. None of the above

**D**

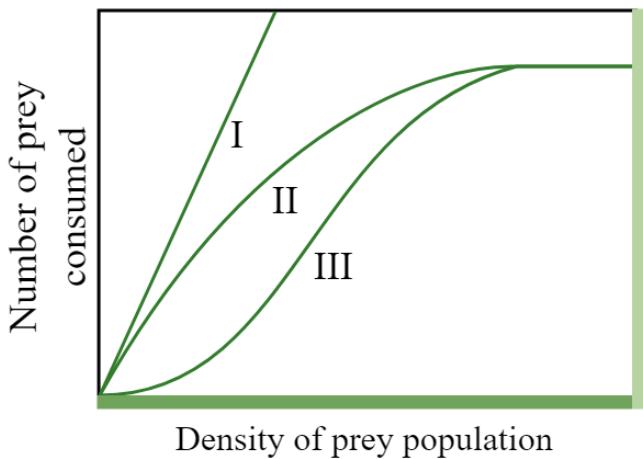
77. [1] HABs can be resilient for a variety of reasons, but one reason is that of rejection as food by zooplankton. This means zooplankton will exhibit \_\_\_\_ top-down control.

- a. High
- b. Little

**B**

### Gotta Love our Holling Curves

The functional response is a core feature in any trophodynamic model and describes the consumption rate of a given prey by a given predator, in other words, the number of prey successfully attacked per predator as a function of prey density (Solomon, 1949; Holling, 1959b). There are three different responses (I, II, III), but only Holling Type III will be discussed here. The Holling Type III curve is described as “[The] number of prey caught per predator per unit time increases slowly at low prey densities, but fast at intermediate densities before leveling off at high densities, producing an S-shaped curve”.



When making food web models, the functional response is important in determining a proper model. This is especially important in a zooplankton system as its functional response greatly affects model output.

78. [2] Interpret/Define the zooplankton functional response (with a Type III curve).

**The zooplankton functional response is defined as the specific food intake rate (i.e. per zooplankton biomass, per unit of time) as a function of ambient food density [+2] | [+1] for decent interpretation (within context)**

The Holling Type III curve is sigmoidal, and it is known that replacing this curve with a non sigmoidal curve would alter model parametrics greatly. When determining the functional response of a predation system, typically laboratory experiments are set up. A lot of experiments have already been done to determine the zooplankton system, but a lot of them say that it follows closely to Holling Type I and/or II rather than III. But when the experiments are revisited, type III behavior is observed in the zooplankton. Realistically, the “correct” model depends on the real environmental conditions. Plankton populations are observed to have vertical stratification which again depend on a whole set of other factors. A model for the grazing rate of zooplankton in the column (per unit volume) that assumes close to homogenous density of plankton across the vertical column is this:

$$E = f(\bar{P})\bar{Z},$$

79. [2] What is P-bar and Z-bar?

**P-bar and Z-bar are the average (over the column) densities of phytoplankton and zooplankton, respectively.**

80. [2] We know that plankton density is not homogenous though throughout the vertical column. Let's say that a phytoplankton bloom occurred. What is the response of the zooplankton to this?

**Zooplankton can adjust their vertical location and feeding at depths of high food concentrations.**

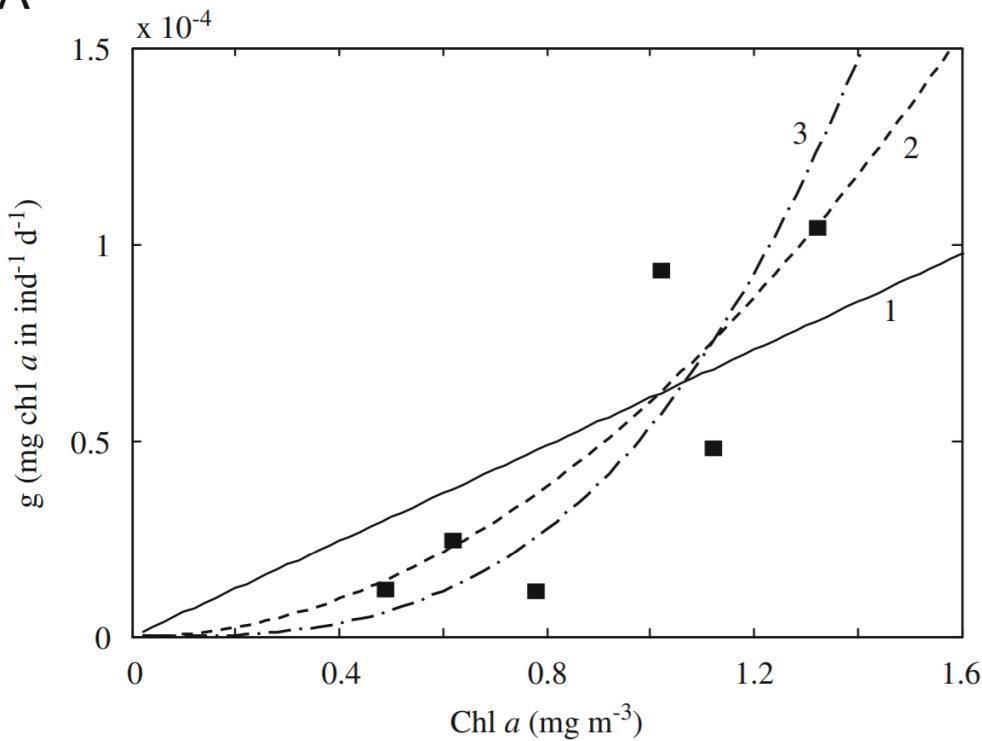
Due to this we change the model for grazing rate to the one shown below. F is the consumption of food in the entire water column and H the depth of the column. ( $P(h)$  and  $Z(h)$  are vertical distributions.)

$$E = \frac{F}{H\bar{Z}}\bar{Z} = g[P(h), Z(h)]\bar{Z},$$

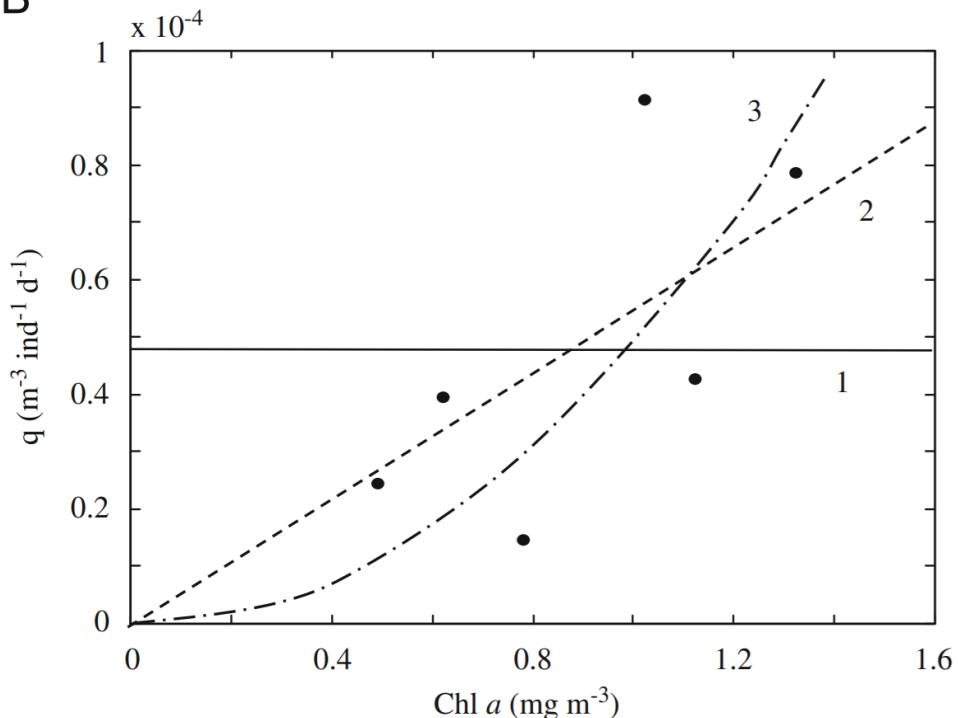
The ratio  $F/HZ\bar{Z}$  is replaced with the function  $g[P(h), Z(h)]$ , where  $g$  will now be our function response.

We take field data from Bautista and Harris (1992) and model them here. The central Barents Sea was the location of this study. The following graphs show the overall functional response,  $g$ , of a copepod (*C. helgolandicus*) plotted versus average chlorophyll density  $P\bar{Z}$  in the water column.

A



B



81. [5] It is important to note that this was taken though March to April, from the pre-bloom period to the beginning of the bloom period. Why must the time period be restricted? Hint: Think about bloom dynamics and succession.

**There is a succession among different algal groups occurring at the peak of the bloom as well as during the post-bloom period [+2]. As such, different algal groups have different nutrition properties [+3] and constructing the functional response as a function of total amount of chlorophyll does not make any sense in this case.**

82. [5] In graph A, (1) is the linear fitting, (2) is the parabolic fitting, and (3) is the cubic fitting. In graph B, (1) is the constant, (2) is the linear fitting, and (3) is the parabolic fitting. Graphs A and B show different quantities though, but B is derived from A. In graph B, q is the clearance rate. Using the given variables of g, P-bar, Z-bar, P(h), Z(h), q, derive an equation for clearance rate.

**q=g/P-bar (in graph A, take the y-axis and divide by x-axis to get graph B or q, it's really easy lol)**

83. [2] The graphs do show the actual functional response! Specifically in regards to graph A, with the best curve fit, which Holling Type Curve does it best represent?

**Type III**

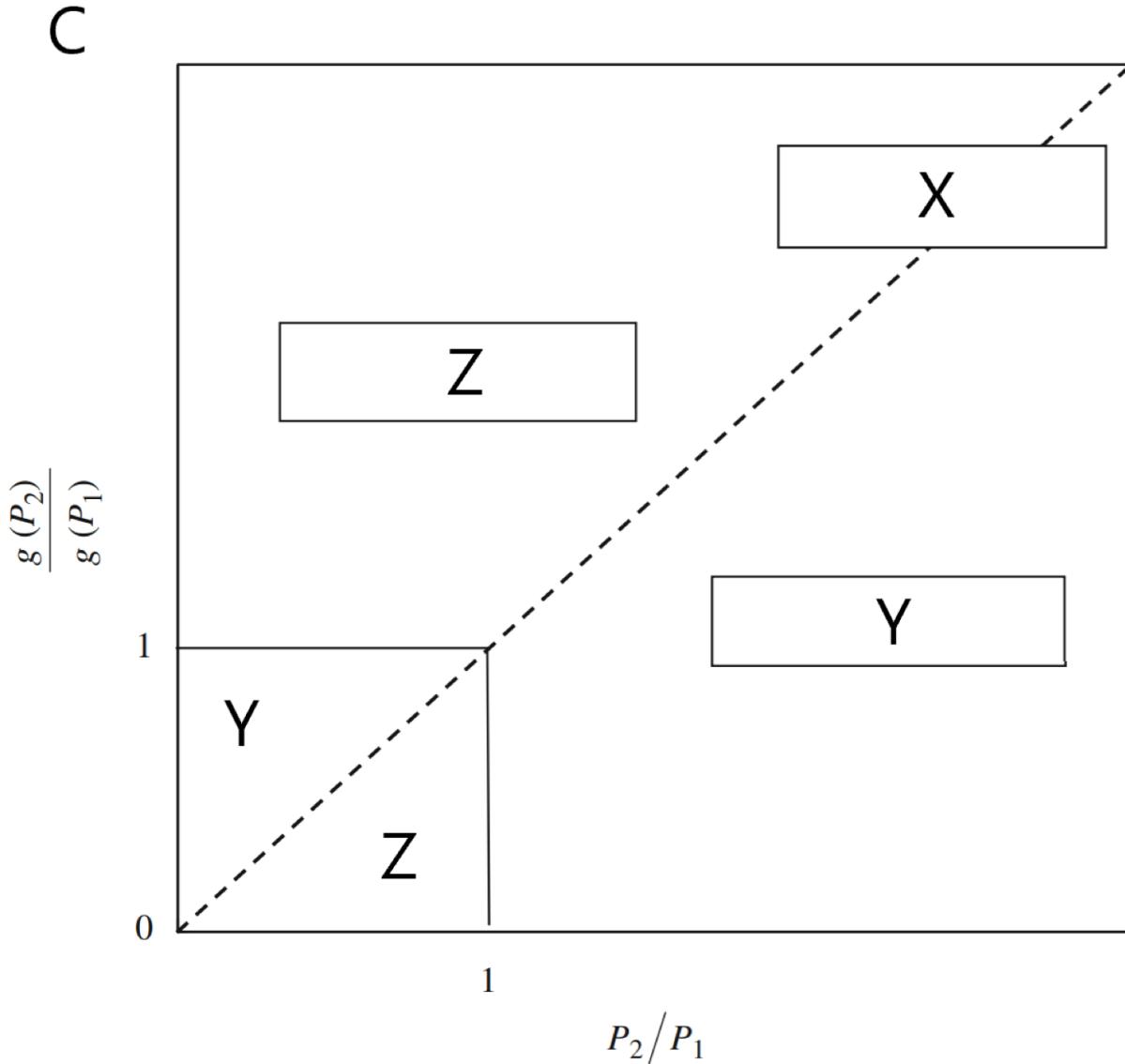
84. [6] Obviously, with the amount of people that say it isn't what it actually shows, graph B supports the type of that curve. Describe the clearance rate of each Holling type curve (I, II, III).

**Type III: clearance rate increases with an increase of food density at low food densities**

**Type II: clearance rate always decreases**

**Type I: clearance rate remains constant**

The following is graph C, another graph to attempt to prove the curve. This is taking the ratio of two functional responses and plankton at any two stations with similar environmental conditions.



85. [8] Identify which Holling type functional responses correspond to X, Y, and Z. Justify your identification of the type I curve.

**X: Type I | Y: Type II | Z: Type III | [+2] each**

**Type 1: an increase of consumption rate would be proportional to the increase of amount of food [+2]**

### Marine Silica Cycle

Silicate is a very important nutrient in our oceans. Although important, it is not needed by every marine organism, but typically utilized most by diatoms, radiolaria, etc. Dissolved silicate in the ocean gets converted to particulate silica, which is a structural material.

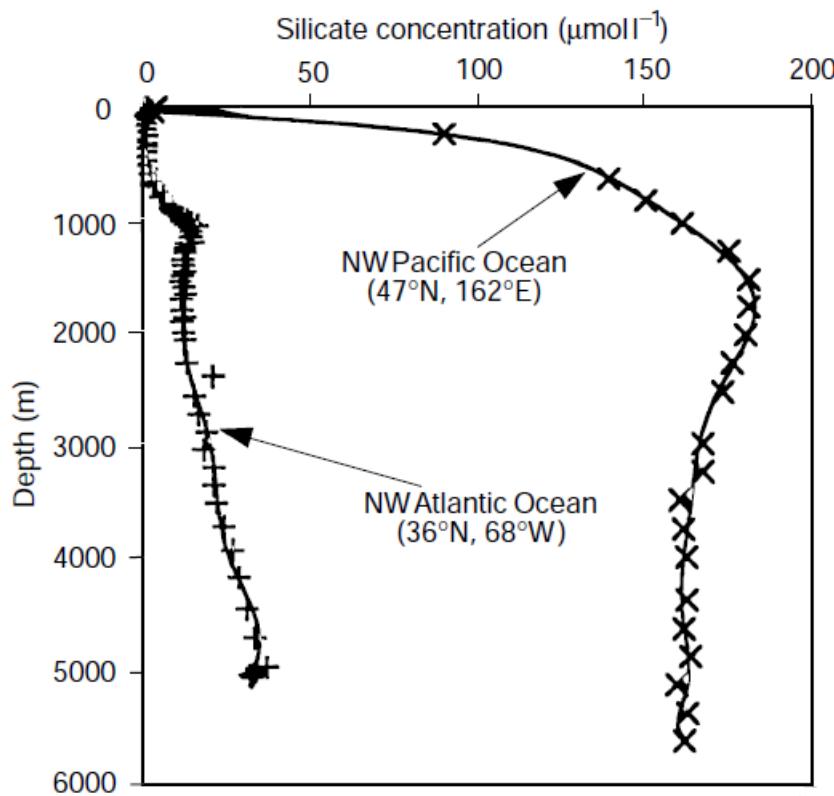
86. [1] What is the chemical formula of silicate and silica, respectively?

**SiO<sub>4</sub> 2-, SiO<sub>2</sub> [+0.5] for each**

87. [2] In the context of silicate cycling, the mean oceanic residence time is important. It is defined as the (amount of dissolved material in a reservoir) / (steady-state flux into or out of the reservoir). Statement: "Dividing the amount of dissolved silicate in the ocean by the supply/removal rate yields a mean oceanic residence time of approximately 10,000 years." Interpret this statement as how you would explain it to someone new to this field.

**Basically, what this means is that an atom of dissolved silicon supplied to the ocean will remain on average in the water column or surface seabed (being transformed between dissolved and particulate material as part of the silicate cycle) for approximately 10,000 years before it is permanently removed from the oceanic system via long-term burial in the seabed.**

The following shows the vertical distribution of dissolved silicate in the Atlantic and Pacific oceans.



88. [1] Deeper waters have much more silicate than surface water in tropical regions. Why is this so? [Do not explain theory behind thermohaline circulation for this, no dynamic planet]

**When siliceous biota die, their skeletons settle through the water column, enriching silicate in deep water.**

89. [1] Chem time! Chemical equilibria of this species (biogenic silica) is incredibly important for many marine species.

Biogenic silica is \_\_\_\_\_ in oceanic waters.

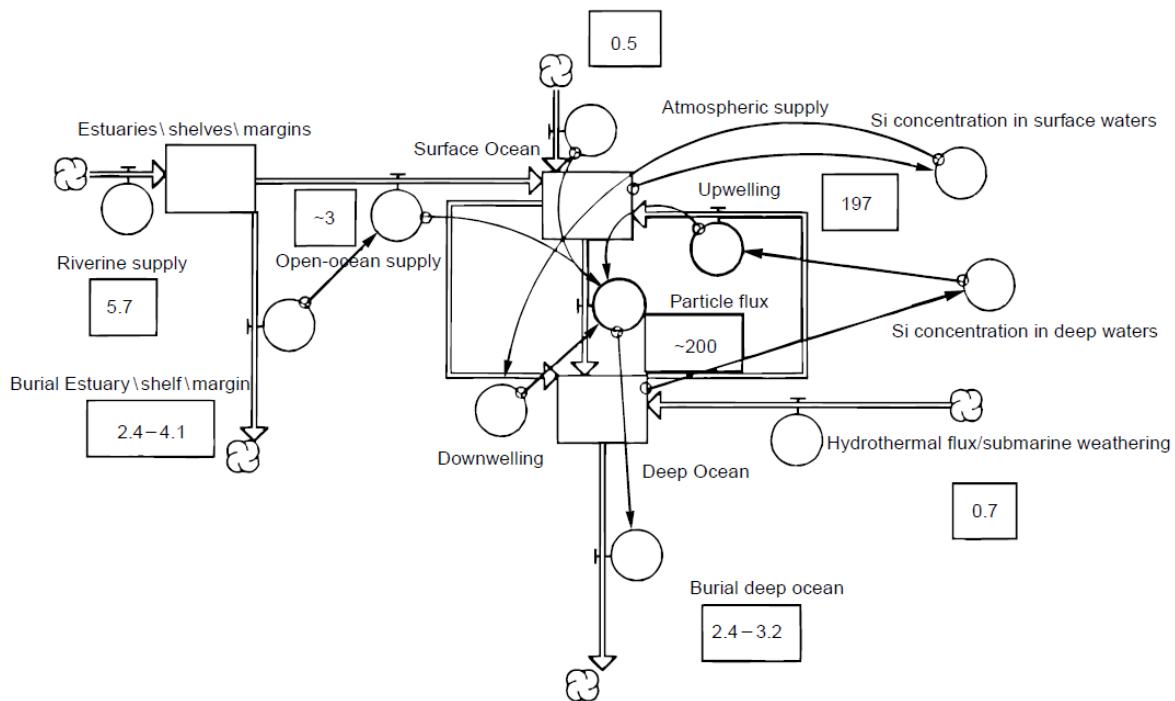
- a. Undersaturated
- b. Supersaturated
- c. Saturated

**A**

90. [2] The saturation state of silica in the ocean forces biota to do what for the formation of their structure?

**Expend a lot of energy to concentrate silicate in their cells before precipitation can occur.**

The following is a diagram of the global silicate cycle. It will be helpful for the next few questions.



91. [1] What is the main source of external silicate to the oceans?

**Rivers/Riverine Supply**

92. [1] A lot of these factors are external, but there are internal ones as well. Oceans upwelling and turbulence are those internal factors. How does the quantity of these internal processes compare with external processes?

**Internal is much much greater**

93. [1] The sediments where there is the highest rate of silica accumulation is beneath coastal upwelling zones.

- a. True
- b. False

**A**

94. [3] Explain why there is a higher rate of silica burial in higher latitudes.

**The high rate of silica burial in the high latitudesediments may be attributed in part to the facts that cold waters occurring at the surface and at depth retard the rate of silica dissolution [+1.5] and that many of the diatom species in high latitudes have more robust skeletons than do their counterparts in lower latitudes [+1.5].**

95. [2] Estuaries typically have high nutrient-flux and rapid sediment burial as well as exhibit high diatom production in surface waters. But there is not much biogenic silica burial, why is this so?

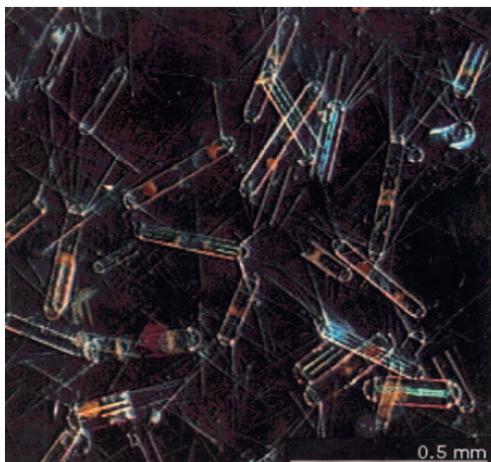
**There is extensive dissolution in the water column.**

96. [1] Which of the following is incorrectly matched with its description? Select ALL that apply.

- a. Diatoms - 20-40% of primary production in the ocean
- b. Radiolaria - Better preservation in sediments than diatoms
- c. Silicoflagellates - Used as a paleo-indicator of upwelling intensity
- d. Siliceous Sponge - Do not exist

**D**

97. [1] Identify this marine organism.



**Diatom**

## Lovely Chemistry

Carbon dioxide is one of the most important gases in our life. Recently, carbon dioxide has come under much discussion, due to the world's increase in carbon emissions and the large amount of CO<sub>2</sub> that is now in our atmosphere. One consequence of this is ocean acidification, which is the focus of this question.

Henry's Law can be used to calculate the solubility of gasses in water. Henry's law states that the solubility of a gas is directly proportional to its partial pressure by a constant known as Henry's constant. The Henry's constant of CO<sub>2</sub> and N<sub>2</sub> are  $2.3 \times 10^{-2}$  mol/(L·atm) and  $7.0 \times 10^{-4}$  mol/(L·atm), respectively.

CO<sub>2</sub> makes up 0.04% of the earth's atmosphere by volume. It is known that the abundance of a gas is proportional to its partial pressure.

98. [2] Calculate the partial pressure of CO<sub>2</sub> (in atm) in the atmosphere, assuming that the atmospheric pressure is 1 atm.

**$4.0 \times 10^{-4}$  atm**

99. [4] Calculate the solubility (in mol/L) of CO<sub>2</sub> in the ocean using Henry's Law.

**$9.2 \times 10^{-6}$  M**

100. [4] Using your value in part b, calculate the pH of the ocean water assuming that no other species besides CO<sub>2</sub> affects the acidity of the ocean. The K<sub>a</sub> of carbonic acid is  $4.3 \times 10^{-7}$ . Assume that all of the dissolved CO<sub>2</sub> is converted into H<sub>2</sub>CO<sub>3</sub>, and that the second deprotonation of carbonic acid is negligible.

**if they did approximate the answer is: 5.70. if they didn't approximate then the answer is 5.75**

101. [3] Would you expect the concentration of dissolved CO<sub>2</sub> in a body of cold water to be greater than, less than, or equal to the concentration of dissolved CO<sub>2</sub> in a body of warm water, assuming that partial pressures of CO<sub>2</sub> are the same.

**greater than, since more gas can dissolve in colder water**

N<sub>2</sub> is the most abundant gas in earth's atmosphere, occupying 78% of the atmosphere's volume. Nitrogen is also very important for our oceans, mostly due to the various nitrogen compounds that are formed by organisms in the ocean.

102. [2] Calculate the solubility of N<sub>2</sub> at standard atmospheric pressure using Henry's Law.

**$5.46 \times 10^{-4}$  M**

Nitrogen fixation done by organisms converts dissolved nitrogen into ammonium ions. The reaction for this is N<sub>2</sub> (aq) + 8H<sup>+</sup> (aq) + 6e<sup>-</sup> → 2NH<sub>4</sub><sup>+</sup> (aq). Do not be concerned about the electrons in the reaction. The equilibrium constant for this reaction is K =  $2.4 \times 10^{26}$ .

103. [2] Write the equilibrium expression for this reaction.

**K = [NH<sub>4</sub><sup>+</sup>]<sup>2</sup>/([N<sub>2</sub>][H<sup>+</sup>]<sup>8</sup>)**

104. [8] Assuming there are no other sources of ammonium ions and using the concentrations found in part C and E, calculate the concentration of ammonium ions in the ocean. To make calculations easier, assume that the concentrations of N<sub>2</sub> and H<sup>+</sup> do not change.

**$5.74 \times 10^{-12}$  M | u know N<sub>2</sub> ( $5.46 \times 10^{-4}$ ) and H<sup>+</sup> ( $10^{-5.7}$ ) and just plug into 103yea**

Scallops our Saviors

105. [2] Acanthaster planci feed selectively upon certain elements of hard corals. Which of the following does not provide a basis for their selection? Select ALL that apply.

- a. Palatability
- b. Accessibility
- c. Prey Defenses
- d. Camouflage

**D**

106. [1] During outbreaks, a form of selection is occurring for heritable traits that enhance host survivorship. This is called predator-induced selection and is associated with the evolution of mutualistic associations. Is the following statement true or false.

Decapod crustaceans, Trapezia & Alpheus, obligate commensals secrete aggressive chemical cues.

- a. True
- b. False

**A**

107. [2] There is a positive association between the pectinid scallop, Pedum spondyloideum, and coral of the genus Porites. Only under high predation pressure, is there an aid in defense. When starfish contact the scallops, the defense reaction is activated. What is this defense mechanism?

**Scallops generate powerful water jets repeatedly**

108. [0.5] What phylum are scallops in?

**Mollusca**

109. [0.5] The Giant Clam is in the same class as scallops.

- a. True
- b. False

**A**

110. [3] Which of the following is false regarding veligers (of the Giant Clam)? Select ALL that apply.

- a. Uses velum for swimming
- b. Exhibit “fright” reaction
- c. Planktotrophic
- d. Wide range of anti-predation responses
- e. Mixotrophic

**DE**

### Population Monitoring

Monitoring populations of aquatic systems is not an easy task. Most of it is based on visual observation, but then what happens to those nocturnal species? Moray eels are nocturnal and our estimates of their influence in aquatic systems is likely to be undercover and biased.

111. [1] Nocturnal species mainly composed of what?

- a. Mostly predatory
- b. Half predatory and half herbivory
- c. Mostly herbivory

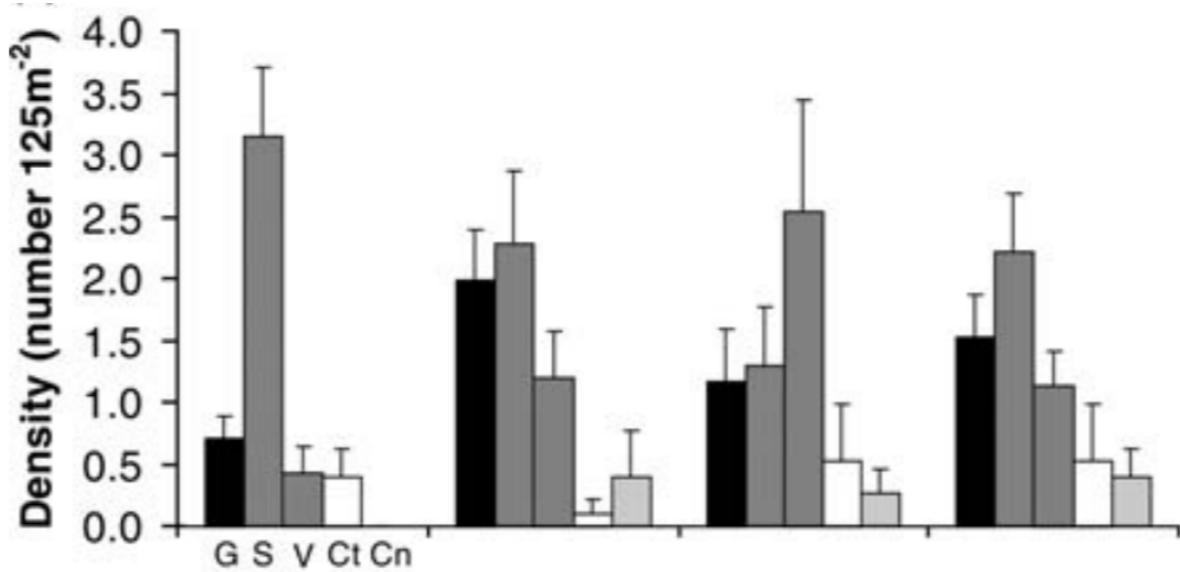
**A**

112. [1] Which of the following are part of the Moray Eel diet? Select ALL that apply.

- a. Fish
- b. Crustacean
- c. Octopi

**ABC**

Moray eels can be mobile and nonmobile, based on how far away they travel from their holes. The residency time in their hole ranges across all species. The following shows a distribution of eel density among 4 sites (from left to right: bank, reverse fringing, non reverse fringing, patch reefs) in Barbados (Adapted from Gilbert et al. 2005). G, S, V, Ct, and Cn correspond to species goldentail, spotted, viper, chestnut, and chain.



113. [3] Almost all species were found in all four reefs. Which species and which reef was there an absence of species?

**Chain [+1.5]; Bank reef [+1.5]**

### Causes of Coral Bleaching

Coral bleaching is a stress response to elevated heat and light levels, where corals lose their algal symbionts (Symbiodiniaceae). Most of the corals' energy comes from their symbionts photosynthetic products.

114. [1] The most understood cause of coral bleaching is one triggered by temperature and light-induced photodamage. This produces what types of molecules that further damage the system?

### **ROS - Reactive Oxidative Species**

115. [1] There are of course other methods of coral bleaching, independent of photo-oxidation. Name another cause of coral bleaching.

**Many answers may include thermal stress, disruption of the coral nutrient metabolism, etc. [+1]**

**[+0.5] for pollution | [+0.75] for acidification**

116. [2] Ammonium ions are the preferred uptake nitrogen source rather than nitrate. Why is this so?

**Nitrate diverts electrons away from photosynthesis, energy cost, but there might be other reasons**

117. [1] Particulate food and moderate levels of ammonium and phosphate tend to benefit coral holobiont health.

- a. True
- b. False

**A**

118. [1] Nitrate negatively impacts the coral holobiont all the time.

- a. True
- b. False

**B**

119. [1] Phosphate limitation limits synthesis and maintenance of important molecules necessary for cell growth. Which of the following molecules require phosphorus?

- a. DNA
- b. Phospholipids
- c. All of the above

**C**

120. [2] Low phosphate conditions can substitute phospholipids for what kind of lipid? Why is this bad?

**Sulfolipids [+1]; compromises the stability of algal symbionts' photosynthetic membranes and renders them susceptible to heat and light stress [+1]**

121. [2] Why is heterotrophic feeding by corals bad under stressful inorganic nutrient conditions?

**exacerbate the nutrient imbalance, heterotrophic nutrient assimilation decreases | only need one reason**

### Coral Diseases

Coral diseases are a cause of decline worldwide. Transmission is the topic that is relatively understudied in regards to disease. There are three hypothesized modes of coral disease transmission: direct contact, water borne, vector-borne.

122. [8] Given the following laboratory methods determine which modes of transmission are being tested for. Some may be testing for multiple.

1. A healthy coral fragment and a coral fragment with an actively progressing disease lesion are placed in an aquarium either in direct contact with each other or placed some distance apart, and then the healthy fragment is monitored for disease development.
2. A healthy fragment and a diseased fragment are placed apart in an aquarium with a potential vector that is able to move freely between the coral fragments.
3. Disease fragments are physically attached to healthy colonies or to healthy fragments that have been reattached to artificial substrate.
4. Snails that are observed interacting with diseased colonies are brought into contact with healthy colonies and/or fragments.

**1: Direct [+1] + Water-borne [+1] | 2: Vector-borne [+2] | 3: Direct [+2] | 4: Vector-borne [+2]**

123. [1] Corals have evolved methods to reduce direct transmission. Explain “contact avoidance” with respect to coral growth.

**growth stops near neighboring colonies and is diverted to other areas**

124. [2] Corals also have chemical and physical attacks against neighboring colonies. Explain a mechanism of physical attack that corals may use.

**Extend mesenterial filaments that injure, sting, and digest tissues on neighboring colonies | needs to be physical**

125. [2] Some colonies are closely related to each other, genetically. These colonies can fuse with each other mediating direct transmission. What is this fusion called?

**Isogeneic fusion [+2]; Allogeneic fusion [+1.5] | either works (I messed up this question)**

126. [1] Gorgonians' support skeletons are relatively flexible. Why may this aid in direct transmission?

**Bending of the colony that could facilitate direct transmission given sufficient water motion**

127. [1] Plastic marine debris is also another factor that mediates disease transmission. Does Vibrio spp. colonize plastic marine debris?

- a. Yes
- b. No

**A**

128. [1] Terrestrial runoff, although seemingly unrelated, contributes to risk of disease. What anthropogenic terrestrial source is most likely to contribute this way?

**Human sewage**

129. [2] Transportation of pathogens over large distances can be mediated by which of the following? Select ALL that apply.

- a. Upwelling
- b. Eddies
- c. Persistent fronts
- d. Internal tides

**ABCD**

130. [4] Coral morphology affects disease transmission. Explain how morphology can increase disease transmission.

**Corals with branching or foliose colony morphology have a greater surface area [+1] exposed to water-borne pathogens compared with mounding or encrusting colony morphologies. Branches create turbulent water flow near the coral surface [+1], which is known to enhance prey capture [+1]. These processes may increase pathogen exposure or aid pathogen attachment [+1].**

131. [1] In non-corallivores, disease transmission is relatively common. Take a blue-spotted goby that was just interacting with a diseased coral. Is there a guarantee that it is able to transmit the disease to another coral? If not, then the gobby is called what instead of a factor?

**Not a guarantee [+0.5]; called a reservoir OR carrier (can not determine between the two) [+0.5]**

132. [2] Why is it hard to determine the exact cause of a lot of coral lesions?

**Corals only exhibit a few immune responses to infection, leading to visually similar disease lesions for a variety of coral diseases with different etiologies.**

133. [1] Which of the following diseases have polymicrobial etiology?

- a. BBD
- b. Caribbean YBD
- c. Pacific YBD
- d. All of the above

**D**

134. [1] Which of the following are detection methods for coral pathogens? Select ALL that apply.

- a. PCR
- b. Dipstick Assay
- c. Fluorescence Microscopy

**ABC**

Situation 1: Buton Tengah Regency

The Buton Tengah Regency area is located in Indonesia and is characterized by a large abundance of karst areas. There is a lot of freshwater and brackish water springs in this region as well.

135. [1] Spring occurrence is dependent on which of the following characteristics of rock recharge? Select ALL that apply.

- a. Topsoil permeability
- b. Bedrock abundance
- c. Porosity

**AC**

136. [3] The water from springs is generally good for consumption use. But the quality of that water is dependent on the mineral layer and the contents of the soil that it goes through. There are three main perspectives involved with the quality of water: physical, chemical, and biological. Give one characteristic for each of those three perspectives.

**Physical: smell, taste, color, etc. | Chemical: hardness, pH, ion content, etc. | Biological: presence/absence of disease-causing microorganisms, etc. [+1] for each**

137. [1] A study was conducted in this area for 30 freshwater springs and 24 brackish water springs. A number of parameters were tested in each of these springs. Which of the following parameters is NOT correctly matched with a plausible method of analysis?

- a. Total Dissolved Solids - Gravimetry
- b. Hardness - Titrimetry
- c. Nitrate - Spectrophotometry
- d. Dissolved Oxygen - Mass Spectrometry

**D**

138. [1] Which of the following is a biological parameter that is correctly matched with its method of analysis?

- a. Biochemical Oxygen Demand - BOD meter
- b. Total Coliform - Most Probable Number
- c. None of the above

**B**

139. [1] Below is the raw data for 13 freshwater springs and their chemical parameters (Adapted from Sudia et al. 2021).

Parameters	Unit	Freshwater 1	Freshwater 2	Freshwater 3	Freshwater 4	Freshwater 5	Freshwater 6	Freshwater 7	Quality Standards
Total Dissolved Solids (TDS)	mg/L	530	300	450	510	600	790	590	1500
Acidity (pH)	-	6.53	6.20	6.04	6.84	6.87	6.77	6.97	6.5–9.0
Hardness ( $\text{CaCO}_3$ )	mg/L	204	275.4	571.2 *	193.8	197.8	332.3	220.3	500
Chloride (Cl)	mg/L	229.5	25.80	25.80	227.6	509.6	553.2	259.9	600
Sulfate ( $\text{SO}_4$ )	mg/L	37	23	28	33	45	66	41	400
Nitrate ( $\text{NO}_3$ )	mg/L	2.10	1.92	1.45	2.9	1.78	2.01	1.02	10
Nitrite ( $\text{NO}_2$ )	mg/L	0.10	0.02	0.02	0.09	0.10	0.02	0.02	1
Iron (Fe)	mg/L	0.02	0.01	<0.01	0.01	0.02	<0.01	0.01	1.0
Dissolved Oxygen (DO)	mg/L	3.03	3.85	3.15	3.59	4.00	3.11	3.52	-
Biological Oxygen Demand (BOD)	mg/L	6.20	5.50	6.11	6.18	5.70	4.99	6.01	-

Parameters	Unit	Freshwater 8	Freshwater 9	Freshwater 10	Freshwater 11	Freshwater 12	Freshwater 13	Quality Standards
Total Dissolved Solids (TDS)	mg/L	330	290	270	370	440	300	1500
Acidity (pH)	-	6.80	6.80	6.84	6.77	7.21	7.32	6.5–9.0
Hardness ( $\text{CaCO}_3$ )	mg/L	240	234.6	150.9	204	248.8	150.2	500
Chloride (Cl)	mg/L	13.83	10.13	40.55	35.94	276.5	230.5	600
Sulfate ( $\text{SO}_4$ )	mg/L	15	8.0	6.0	7.0	15	10	400
Nitrate ( $\text{NO}_3$ )	mg/L	0.99	1.81	3.10	1.56	2.06	1.81	10
Nitrite ( $\text{NO}_2$ )	mg/L	0.02	0.02	0.12	0.02	0.03	0.02	1
Iron (Fe)	mg/L	0.01	0.02	<0.01	0.02	0.01	0.03	1.0
Dissolved Oxygen (DO)	mg/L	3.33	3.71	3.81	3.79	3.50	3.60	-
Biological Oxygen Demand (BOD)	mg/L	5.60	7.02	6.10	6.21	4.88	6.40	-

Which freshwater spring seems to have a chemical parameter that exceeds the water quality standards? Which chemical parameter is it exceeding?

**Freshwater 3 [+0.5]; Hardness [+0.5] <- best answer but they can do freshwater 2 with acidity**

140. [2] Below is the raw data for 5 brackish water springs and their chemical parameters.

Parameters	Unit	Brackish 1	Brackish 2	Brackish 3	Brackish 4	Brackish 5	Quality Standards
Total Dissolved Solids (TDS)	mg/L	940	13,000 *	12,000 *	13,600 *	850	1500
Acidity (pH)	-	7.05	6.99	7.17	7.15	7.30	6.5–9.0
Hardness ( $\text{CaCO}_3$ )	mg/L	303.9	461	410	493	338.6	500
Chloride (Cl)	mg/L	414	691 *	4562 *	1059 *	599	600
Sulfate ( $\text{SO}_4$ )	mg/L	72	97	95	99	64	400
Nitrate ( $\text{NO}_3$ )	mg/L	3.81	3.41	3.80	3.66	2.02	10
Nitrite ( $\text{NO}_2$ )	mg/L	0.11	0.10	0.04	0.11	0.02	1
Iron (Fe)	mg/L	0.02	0.03	0.02	0.01	0.02	1.0
Dissolved Oxygen (DO)	mg/L	3.61	2.65	2.65	3.81	3.96	-
Biological Oxygen Demand (BOD)	mg/L	5.66	5.70	5.70	6.11	6.03	-

Which brackish water springs has the most amount of chemical parameters exceeded? If the maximum number of chemical parameters is equal among different springs, indicate that. Which parameter(s) are being exceeded?

**Brackish 2,3,4 [+1] all or nothing; TDS [+0.5]; Chloride [+0.5]**

141. [1] High hardness is related to which two atoms/ions of salts dissolved in water?

**Mg [+0.5]; Ca [+0.5]**

142. [3] Bicarbonate ions complexed with the previous two cations instead of carbonate is called what kind of hard water?

Why is it called this?

**Temporary [+1] hard water; hardness is lost by heating bicarbonate ions to form carbonate deposits lowering Ca<sup>2+</sup> and Mg<sup>2+</sup> due to precipitation [+2]**

143. [1] Water hardness has multiple classifications. Which of the following concentrations is not accurately classified with its qualitative definition? Select ALL that apply.

- a. 30 mg/L - soft
- b. 80 mg/L - soft
- c. 100 mg/L - moderately hard
- d. 125 mg/L - moderately hard
- e. 200 mg/L - hard/very hard

**BD**

144. [5] With the levels of hardness in the brackish springs that you identified, explain why high levels are/can be detrimental in the context of (1) soap and (2) pipes/boilers.

- (1) **Deposition of soap anions [+1], which reduce the effectiveness of washing and lead to wasteful soap consumption [+0.5]. When hard water meets soap, what happens is the ions contained in the hard water destroy the surfactant effect of the soap [+0.5]. When they meet, they form a solid deposit (soap scum [+1]).**
- (2) **Forming calcium and magnesium salts that are difficult to dissolve in water [+0.5] (for example, calcium carbonate (CaCO<sub>3</sub>) and magnesium carbonate (MgCO<sub>3</sub>)). This sediment salt often settles in the pipe or boiler [+1], and if left for a long time, can cause blockage and damage to the boiler or pipe [+0.5].**

145. [4] When there is water with high hardness, there must be solutions to lower these levels. Explain in detail how the addition of lime and soda ash can lower hardness.

**The addition of lime (CaO) and soda ash (Na<sub>2</sub>CO<sub>3</sub>) is quite effective. Lime and soda ash can raise the pH [+0.5] and supply CO<sub>3</sub><sup>2-</sup> ions [+0.5], which are needed to precipitate Ca<sup>2+</sup> ions into calcium carbonate (CaCO<sub>3</sub>) [+1]. Meanwhile, a relatively high pH [+0.5] can cause Mg<sup>2+</sup> ions to be deposited in Mg(OH)<sub>2</sub> compounds [+1], which can be separated from the solution [+0.5].**

146. [1] Explain how to perform a dilution technique to lower hardness.

**Mix pure (non-hard) water with water that has a high hardness level [+1], which will reduce the concentration of Ca<sup>2+</sup> and Mg<sup>2+</sup> ions so that the hardness level can decrease.**

147. [1] Zeolite crystals are used in many treatment plants to reduce hardness. It is effective due to its high ion exchange capacity. Is the charge of zeolites typically negative or positive?

- a. Negative
- b. Positive

**A**

148. [1] TDS refers to any minerals, salts, metals, cations, or anions dissolved in water. Which of the following are considered part of TDS? Select ALL that apply.

- a. Woodgrain
- b. Nitrate
- c. Sodium
- d. Pesticides

**BCD**

149. [2] Why is the quality of groundwater very dependent on rainfall in coastal regions. Which ion is most likely to increase in dry seasons?

**In the dry season, freshwater from rainwater is no longer available, so groundwater will be easily contaminated by seawater. Pollution of groundwater quality as a result of seawater contamination is called an intrusion [+1]. The characteristic of seawater intrusion is groundwater that feels brackish or contains high levels of chloride [+1] and TDS.**

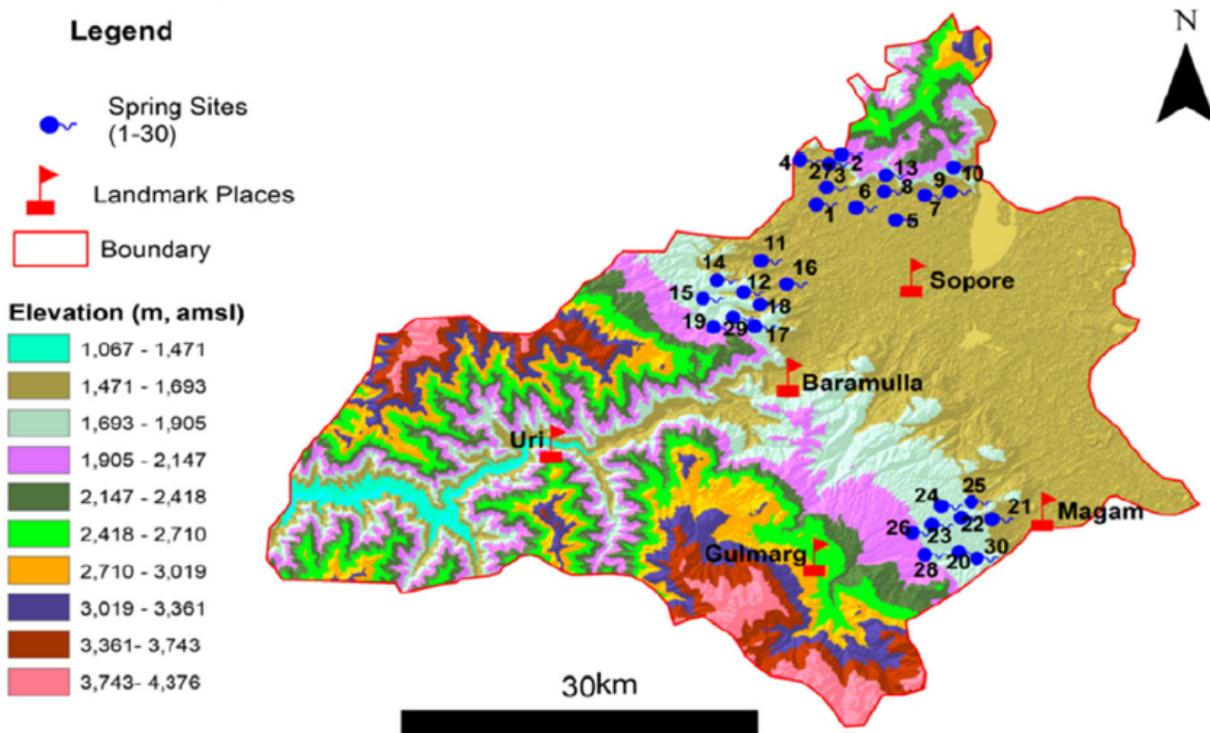
### Situation 2: Kashmir

150. [1] Which of the following is false about springs?

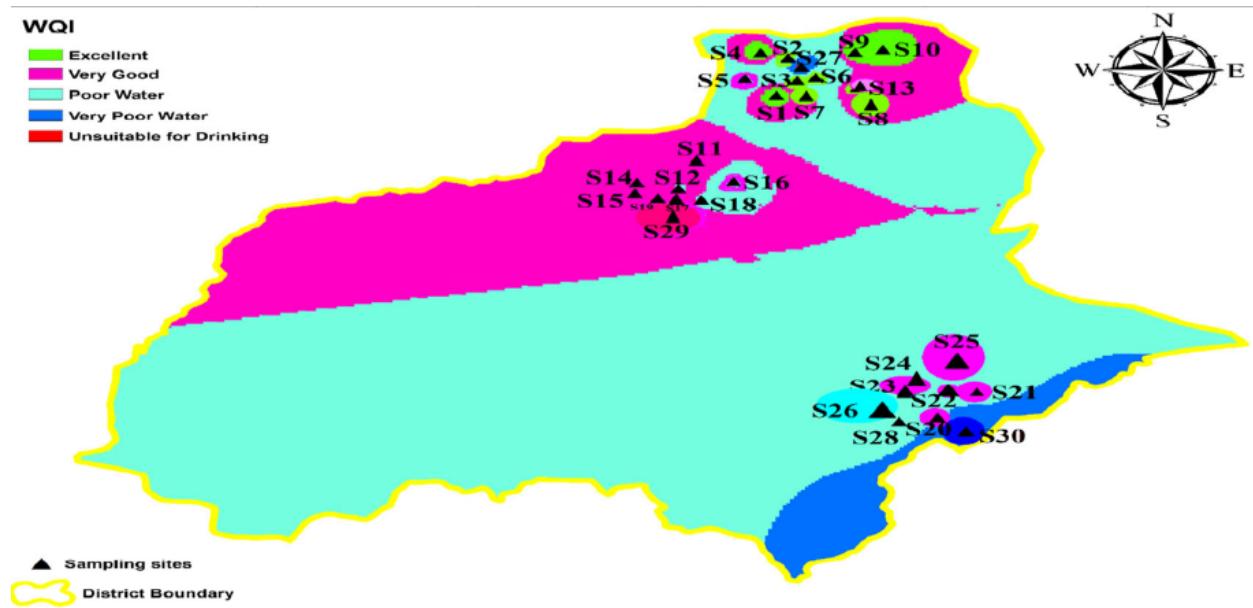
- They act as an interface between the aquatic and terrestrial habitat.
- They are an ecotone providing their own characteristic environment for the organisms living in and around springs.
- They have a transitory character as they behave simultaneously as ground and surface water systems
- None of the above are false

D

Another study was conducted in Kashmir (near the Himalayas) with 30 different springs (Adapted from Bhat et al. 2020). The valley of Kashmir is of tectonic origin. The mountains surrounding the valley are snow-covered year-round.



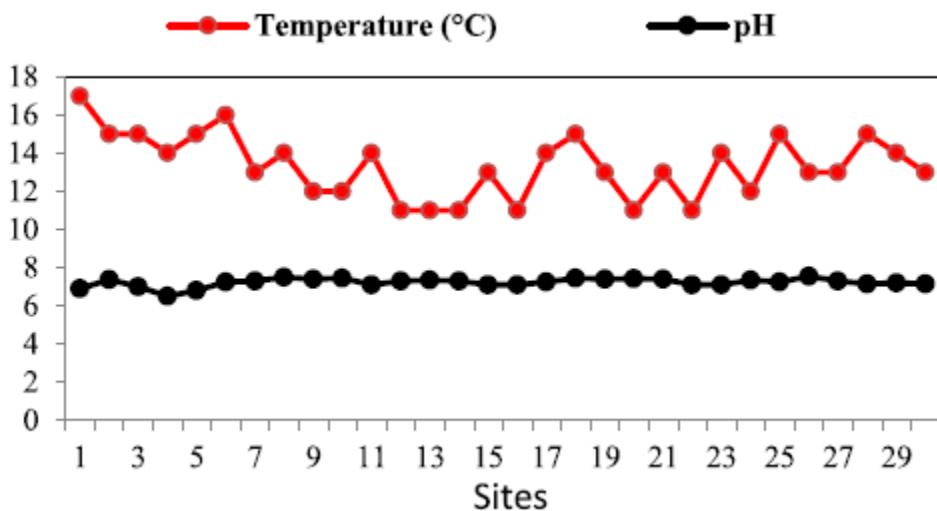
151. [2] The following is a map of the WQI and its geographical distribution in the Kashmir region.



The calculation for the WQI index was through a weighed index method.

Rank the geographical areas of the WQI levels (excellent, very good, poor water, very poor water, unsuitable for drinking) by area from least to greatest.

**Unsuitable, Excellent, Very Poor Water, Very Good, Poor Water | all or nothing**



152. [1] What is the range of the water temperature across all of the sites?

**10/11 - 17 C OR 6/7 C**

153. [1] The pH of these springs follows the regulations set by the WHO for drinking water.

- a. True
- b. False

**A**

154. [1] In a graph showing TDS and EC (electrical conductivity), would you expect a positive correlation, negative correlation, or no relationship between the two?

**Positive correlation**

155. [1] NO<sub>2</sub>-N was ranging from 10 to 25 µg/l. Why is the concentration of this typically low?

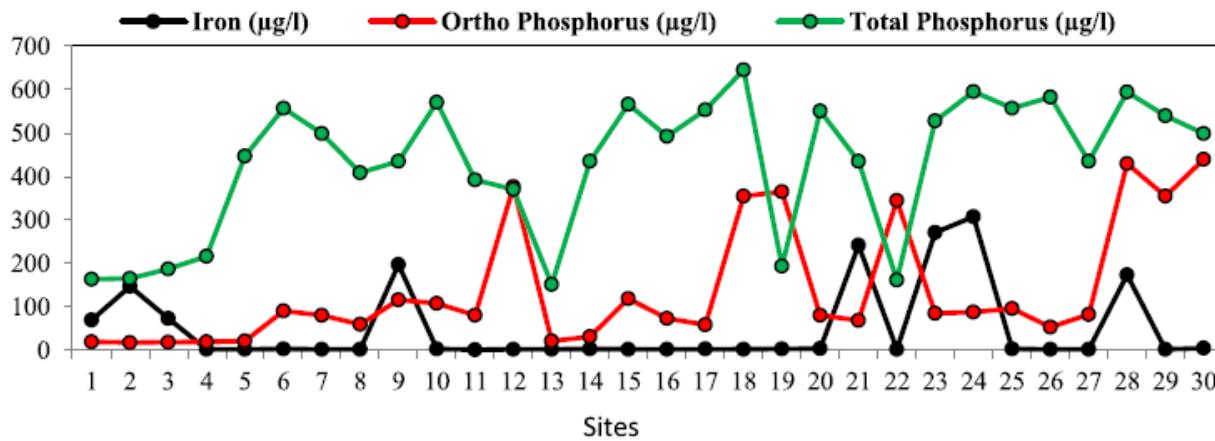
**It is very unstable and quickly gets converted into NO<sub>3</sub>-N and therefore found in less concentration.**

156. [1] The high affinity of soils for the retention of phosphorus coupled with high solubility of phosphate minerals, tends to keep phosphorus concentration to remain low.

- a. True
- b. False

**B**

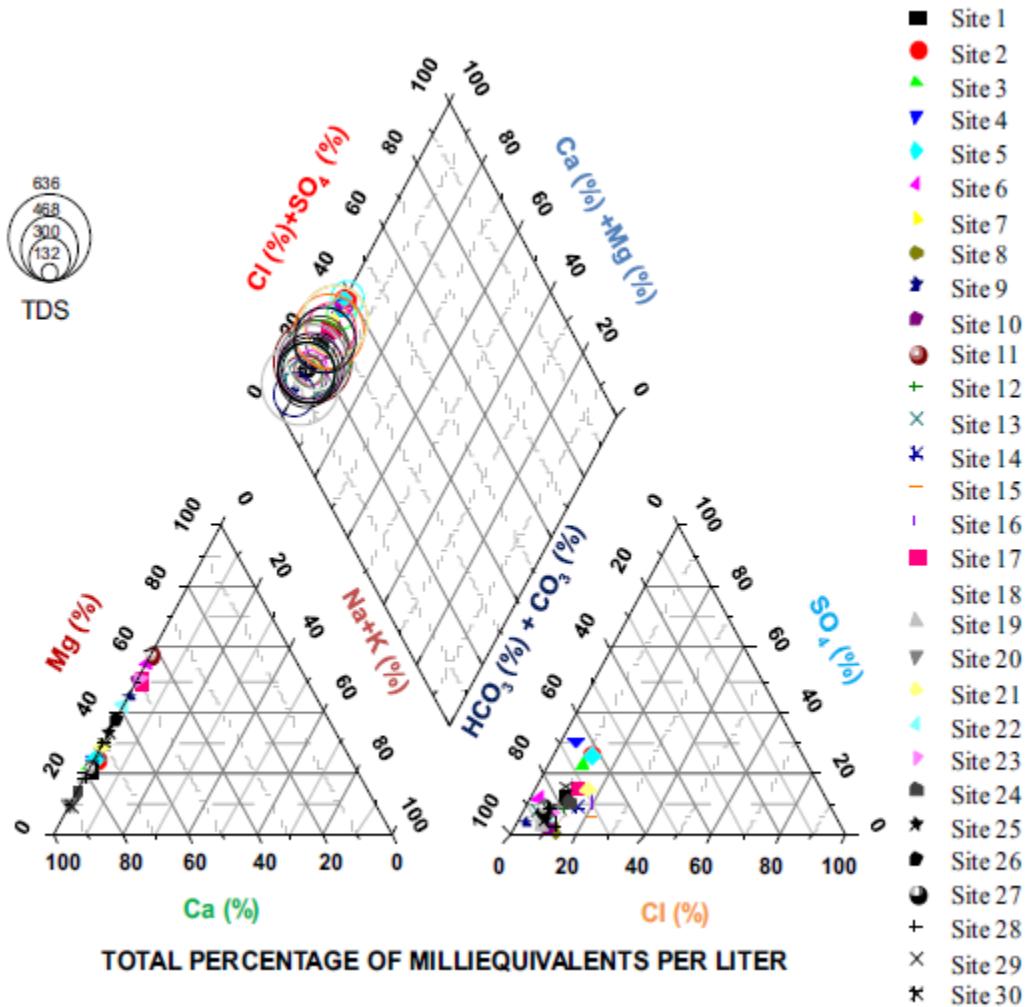
157. [1] The region has very low industrial development. Where are these fluctuating iron levels coming from?



- a. Lithogenic source
- b. Anthropogenic source
- c. None of the above

**A**

158. [3] What is the name of this diagram?



Piper trilinear diagram (also called piper diagram)

159. [2] You can see how ions got concentrated on the left quadrant of the diamond plot of this diagram. This indicates that the composition of the water is mainly influenced by what?

Mostly influenced by the lithology of the catchment area OR influenced by Ca/Mg